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Estimation of Sockeye Salmon Escapement into McLees Lake, Unalaska Island, Alaska, 2007

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Anchorage, Alaska
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Jeffry L. Anderson and Michael R. Edwards

Abstract

The Anchorage Fish and Wildlife Field Office operated a fixed picket weir at the outlet of McLees Lake on Unalaska Island from 1 June to 27 July 2007. A total of 21,428 sockeye salmon *Oncorhynchus nerka* were counted through the weir. Peak daily passage occurred on 1 July when 1,017 sockeye salmon were counted through the weir. Nine hundred sixty-nine sockeye salmon were sampled for age, sex, and length analysis. Of this sample 157 (16%) scales were unreadable. Five age classes were identified from the 812 readable scales. Ages 1.3 (87%) and 2.3 (9%) accounted for 96 % of the sample. Females comprised an estimated 38 % of sockeye salmon sampled in 2007.

Introduction

The McLees Lake watershed provides important spawning and rearing habitat for sockeye salmon *Oncorhynchus nerka* and also provides one of the few opportunities for residents of Unalaska to harvest subsistence salmon. The Reese Bay subsistence fishery has accounted for approximately 87% of the annual salmon harvest for this community since 1997 (Tschersich 2007). Subsistence harvest of sockeye salmon returning to McLees Lake has been monitored since 1985, and harvests have ranged from 436 to 4,694 sockeye salmon (Tschersich 2007). Since 1985, the number of subsistence permits issued for this fishery has steadily increased; the average number of permits issued from 2000 to 2006 was 214. Annual fluctuations in harvest have generally corresponded to the number of permits issued for the fishery. Since 1995, the average annual harvest has nearly doubled and the number of permits issued has nearly tripled from that observed from 1985-1994. These numbers suggest that sockeye salmon returning to McLees Lake have become increasingly important to the local subsistence fishery.

The spawning escapement of sockeye salmon to McLees Lake has been monitored using aerial survey counts since 1974. Aerial surveys have generally been limited to one survey each year, and counts have ranged from 300 to 34,000 fish (Arnie Shaul, Alaska Department of Fish and Game, personal communication). Aerial counts potentially serve as an index of abundance, but can be influenced by several factors including time of survey, poor weather, lack of suitable aircraft, and variation among observers. No aerial surveys were conducted during some years because of weather or aircraft availability; and no surveys have been conducted since 2003. Prior to 2001, management of the fishery was limited to aerial surveys and harvest data to assess escapement.

Local residents and the Alaska Department of Fish and Game (ADF&G) have expressed concerns that the lack of an escapement estimate for sockeye salmon into McLees Lake may jeopardize the health of the run, as well as future opportunities for subsistence fishing. These concerns prompted the Kodiak/Aleutians Federal Subsistence Regional Advisory Council to identify an escapement monitoring project on McLees Lake as a high priority. To address these concerns, the U. S. Fish and Wildlife Service (USFWS) and the Qawalangin Tribe of Unalaska entered into a partnership agreement to monitor the sockeye salmon return to McLees Lake from 2001 to 2003, and the USFWS Office of Subsistence Management provided funding to the Kenai

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Fish and Wildlife Field Office for the work through the Fisheries Resource Monitoring Program as project number FIS 01-059. Monitoring continued with the King Salmon Fish and Wildlife Field Office from 2004 to 2006 as project FIS 04-404; beginning in January 2007, the King Salmon office has become the Fisheries Branch of the Anchorage Fish and Wildlife Field Office (AFO). The McLees Lake sockeye salmon escapement project is currently funded through 2009 as project FIS 07-405. Specific objectives of the project are to:

1. Enumerate the daily passage of sockeye salmon through the weir,
2. Describe the run-timing, or proportional daily passage, of sockeye salmon through the weir,
3. Estimate the sex and age composition of sockeye salmon such that simultaneous 90% confidence intervals have a maximum width of 0.20, and
4. Estimate the mean length of sockeye salmon by sex and age.

Palmer (2002; 2003), Gates and Palmer (2004), Edwards (2005; 2006), and Edwards and Hildreth (2005) summarized past project results; this report summarizes findings for the 2007 season.

Study Area

McLees Lake empties into the Bering Sea at Reese Bay on the north side of Unalaska Island approximately 19 km northwest of the city of Unalaska (Figure 1). The McLees Lake watershed drains an area of approximately 41 km^2, and consists of a 3.98 km^2 lake with several small tributaries. The McLees Lake outlet stream is a fast moving high gradient stream that flows about 100 m before entering Reese Bay. Salmon often stage in Reese Bay and enter the McLees Lake system when migration conditions are optimal. The subsistence fishery targets salmon that are staging in Reese Bay.

The McLees Lake watershed supports spawning populations of sockeye salmon, coho salmon *O. kisutch*, and Dolly Varden *Salvelinus malma*; chum *O. keta* and pink *O. gorbuscha* salmon are also present, but in limited numbers. Chinook salmon *O. tshawytscha* and steelhead *O. mykiss* have also been observed at the weir site.

Methods

Escapement Monitoring

A flexible picket weir spanning 21 m was installed at the outlet of McLees Lake and operated from 1 June to 27 July 2007. Weir pickets were composed of metal electrical conduit with a 1.3-cm inside diameter. Picket spacing ranged from 3.5 cm for panels in shallow water near each stream bank to 2.2 cm on panels near the middle of the outlet channel. All pickets were 1.5-m long and strung together with 3-mm diameter aircraft cable to make panels that spanned about 3 m. A spanning cable (6-mm diameter) was extended bank-to-bank and pulled tight about 0.3 m above the surface of the water. The weir panels were supported by the spanning cable, which was supported with two wooden tripods evenly spaced across the channel and fence posts spaced approximately every 3 m. To prevent fish from squeezing between the weir pickets, plastic snow fencing with 2.2 cm square mesh was attached to the downstream side on the bottom third of each weir panel. A live trap was constructed on the upstream side of the weir to facilitate sampling fish and passing adult salmon through the weir. The weir and live trap were inspected

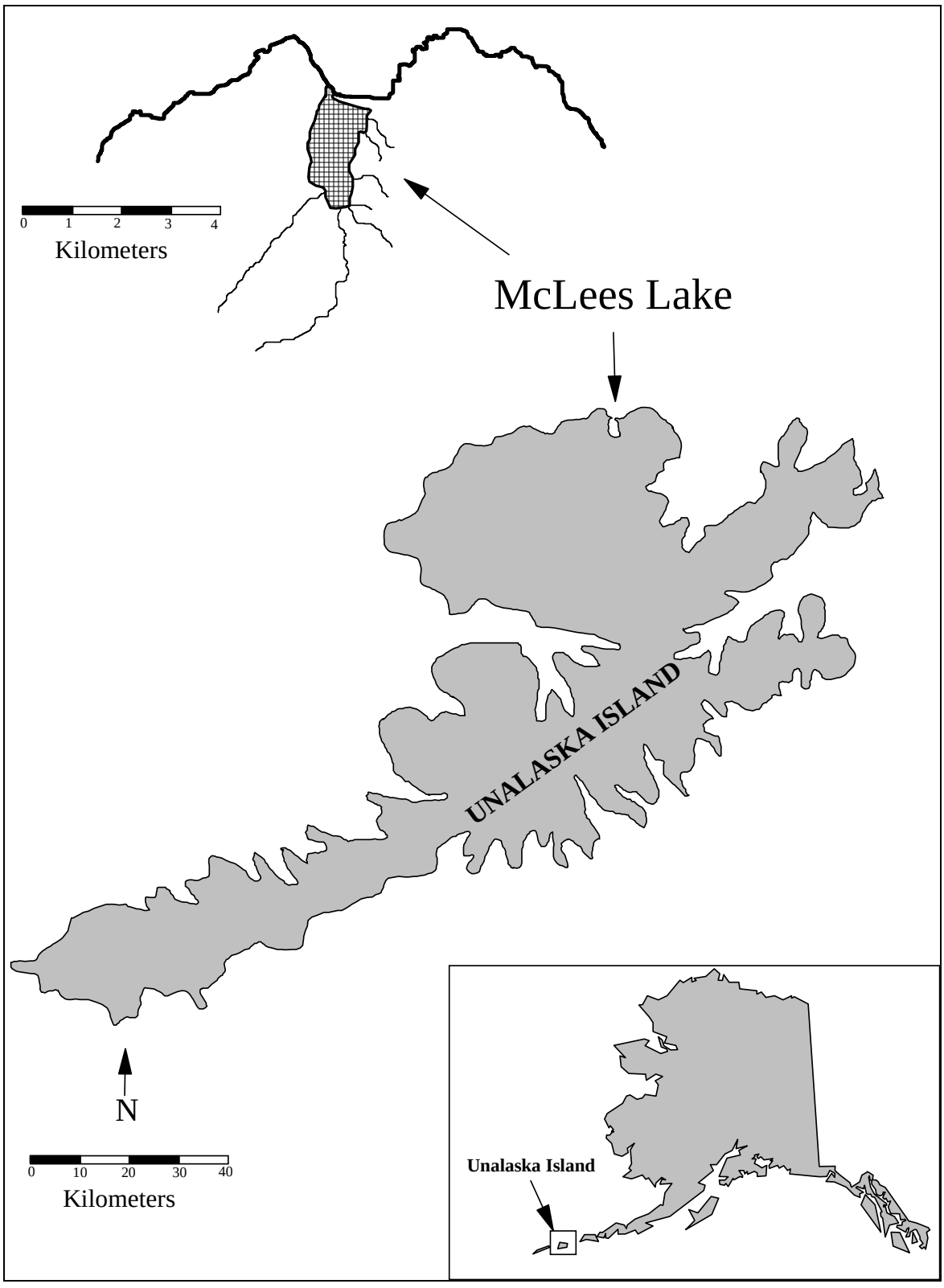

Figure 1. Map of Unalaska Island, southwest Alaska, showing location of McLees Lake study area.

daily and maintained as needed to ensure integrity. Stage height was measured in the morning and evening from a staff gauge located in the outlet channel.

Fish were passed and counted intermittently between 07:00 and 24:00 hours each day. The duration of each counting session varied depending on the number of fish arriving at the weir. Escapement counts were relayed to AFO via satellite phone, and the AFO reported escapement information to ADF&G managers (via e-mail) to support in-season management of the Reese Bay subsistence fishery.

Age, Sex, and Length Data

We collected sockeye salmon age, sex, and length (ASL) data using a temporally stratified sampling design (Cochran 1977) with statistical weeks defining strata. Samples were collected uniformly throughout the week (Sunday through Saturday). To avoid potential bias caused by the selection or capture of individual fish, all target species within the live trap were included in the sample even if the sample size goal for a species was exceeded. Although weir passage was stratified into statistical weeks a priori, strata for the analysis of sockeye salmon biological data at the McLees Lake weir were modified following the field season to represent actual weir passage (Table 1).

Samples for ASL data were collected using a dip net to remove fish from the live trap at least once daily or more often as the number of fish moving through the weir increased. Adult salmon were measured to the nearest mm (mid-eye to tail fork) and the sex of the fish was determined from secondary characteristics. One scale from each sockeye salmon was removed from the preferred area on the left side of the fish (Jearld 1983), cleaned, and mounted on gummed scale cards. Sockeye salmon scales were pressed and aged following the field season by ADF&G personnel. Salmon ages are reported according to the European method described by Jearld (1983) and Mosher (1968) where the number of winters the fish spent in fresh water and in the ocean is separated by a decimal. Fish with scales that could not be aged were not included in the age analyses. Non-target fish captured in the live trap were identified to species, enumerated, and released above the weir.

Maximum weekly sample size goals for sockeye salmon were established such that simultaneous 90% interval estimates of age composition for each week have maximum widths of 0.20 based on a multinomial sampling model (Bromaghin 1993). The weekly sample size determined from Bromaghin (1993) was $n = 121$ based on four age categories, and was increased to 135 to account for the expected number of unreadable scales (about 10% in past years). For some weeks, the sample size goal was expected to be a substantial fraction of the sockeye salmon passage. Therefore, during weeks of low passage when the maximum sample size goal could not be practically obtained, about 20% of the weekly escapement was sampled. This was sufficient to describe the age composition and reduce the number of fish handled at the weir.

Table 1. Strata (time periods) used for analysis of sockeye salmon biological data at McLees Lake, 2007.

Stratum	Dates
1	1 - 9 June
2	10 - 16 June
3	17 - 23 June
4	24 - 30 June
5	1 - 7 July
6	8 - 14 July
7	15 - 21 July
8	22 - 28 July

Characteristics of sockeye salmon passing through the weir were estimated using standard stratified random sampling estimators (Cochran 1977). Within a given stratum *m*, the proportion of species *i* passing the weir that are of sex *j* and age *k* (p_{ijkm}) was estimated as

$$\hat{p}_{ijkm} = \frac{n_{ijkm}}{n_{i++m}},$$

where n_{ijkm} denotes the number of fish of species *i*, sex *j*, and age *k* sampled during stratum *m* and a subscript of "+" represents summation over all possible values of the corresponding variable, e.g., n_{i++m} denotes the total number of fish of species *i* sampled in stratum *m*. The variance of $\hat{p}_{ijkm}$ was estimated as

$$\hat{v}(\hat{p}_{ijkm}) = \left(1 - \frac{n_{i++m}}{N_{i++m}}\right) \frac{\hat{p}_{ijkm}\left(1 - \hat{p}_{ijkm}\right)}{n_{i++m} - 1},$$

where N_{i++m} denotes the total number of species *i* fish passing the weir in stratum *m*. The estimated number of fish of species *i*, sex *j*, age *k* passing the weir in stratum *m* ($\hat{N}_{ijkm}$) was

$$\hat{N}_{ijkm} = N_{i++m}\,\hat{p}_{ijkm},$$

with estimated variance

$$\hat{v}(\hat{N}_{ijkm}) = N_{i++m}^2\,\hat{v}(\hat{p}_{ijkm}).$$

Estimates of proportions for the entire period of weir operation were computed as weighted sums of the stratum estimates, i.e.,

$$\hat{p}_{ijk} = \sum_m \left(\frac{N_{i++m}}{N_{i+++}} \right) \hat{p}_{ijkm} ,$$

and

$$\hat{v}\left(\hat{p}_{ijk}\right) = \sum_m \left(\frac{N_{i++m}}{N_{i+++}} \right)^2 \hat{v}\left(\hat{p}_{ijkm}\right).$$

The total number of fish in a species, sex, and age category passing the weir during the entire period of operation was estimated as

$$\hat{N}_{ijk} = \sum_m \hat{N}_{ijkm} ,$$

with estimated variance

$$\hat{v}\left(\hat{N}_{ijk}\right) = \sum_m \hat{v}\left(\hat{N}_{ijkm}\right).$$

If the length of fish of species *i*, sex *j*, and age *k* sampled in stratum *m* is denoted x_{ijkm}, the sample mean length of fish of species *i*, sex *j*, and age *k* within stratum *m* was calculated as

$$\bar{x}_{ijkm} = \frac{\sum x_{ijkm}}{n_{ijkm}},$$

with corresponding sample variance s^2_{ijkm}

$$s^2_{ijkm} = \left(1 - \frac{n_{ijkm}}{\hat{N}_{ijkm}} \right) \frac{\sum \left(x_{ijkm} - \bar{x}_{ijkm} \right)^2}{n_{ijkm} - 1} .$$

The mean length of all fish of species *i*, sex *j*, and age *k* ($\hat{\bar{x}}_{ijk}$) was estimated as a weighted sum of the stratum means, i.e.,

$$\hat{\bar{x}}_{ijk} = \sum_m \left(\frac{\hat{N}_{ijkm}}{\hat{N}_{ijk}} \right) \bar{x}_{ijkm} .$$

An approximate estimator of the variance of $\hat{\bar{x}}_{ijk}$ was obtained using the delta method (Seber 1982),

$$\hat{v}\left(\hat{\bar{x}}_{ijk}\right) = \sum_m \left\{ \hat{v}\left(\hat{N}_{ijkm}\right) \left[\frac{x_{ijkm}}{\sum_x \hat{N}_{ijkx}} - \sum_y \frac{\hat{N}_{ijky}}{\left(\sum_x \hat{N}_{ijkx} \right)^2} x_{ijky} \right]^2 + \left(\frac{\hat{N}_{ijkm}}{\sum_x \hat{N}_{ijkx}} \right)^2 s^2_{ijkm} \right\}.$$

Results

Escapement Monitoring

Operation of the McLees Lake weir began on 1 June and continued uninterrupted through 27 July 2007, and 21,428 sockeye salmon were counted through the weir (Figure 2; Appendix A). Peak daily passage occurred on 1 July when 1,017 sockeye salmon were counted through the weir (Appendix A). Sockeye salmon were passed through the weir every day from 4 June until it was removed on 27 July. Thirteen sockeye salmon mortalities were observed at the weir in 2007. Fish died after becoming trapped between pickets while attempting to jump through the weir just above the water surface.

Two pink, two coho, and one Chinook salmon were also counted through the weir in 2007. Three steelhead were observed near the weir and live trap from about 20 June until the weir was removed on 27 July; two of the three were captured for verification. Dolly Varden were observed passing through the weir and were captured in the live trap but were not counted.

High water caused by snowmelt and high winds affected weir operations from 26 to 27 June 2007. Water was observed flowing around the weir on 26 June, and a small passage area was open for approximately 8 hours on the west bank. The crew was able to extend the weir using temporary sections, and no fish were observed passing through the breached section. Fish were also observed jumping over the weir on 27 June, and a temporary vertical extension was added to prevent this. The water levels remained high at the weir for several days following the event, but the weir was only breached on the one occasion.

Age, Sex, and Length Data

Nine hundred sixty-nine sockeye salmon were sampled for age, sex, and length analysis. Of this sample, 157 (16%) scales were unreadable. Five age classes were identified from the 812 readable scales. Ages 1.3 (87%) and 2.3 (9%) accounted for 96 % of the sample (Table 2). Females comprised an estimated 38% of sockeye salmon sampled in 2007 (Table 3). Lengths of sockeye salmon sampled ranged from 449 to 592 mm for females and from 458 to 637 mm for males (Table 4; Figure 3).

Discussion

It is unlikely that many sockeye salmon entered McLees Lake prior to weir installation on 1 June. The first sockeye salmon was not observed at the weir until 4 June, three days after the weir was installed and fish-tight. However, sockeye salmon were still migrating past the weir site when it was removed on 27 July. We do not believe that a large component of the run entered the system after weir removal because daily passage rates had been less than 1% of the total escapement since 18 July (Appendix A). Also, although the weir was breached on one bank for 8 hours in June, the crew does not think that a large number of fish passed upstream because of the small size of the hole and the shallow water depth in the area.

Sockeye salmon mortalities have been observed at the weir since 2004 (Edwards 2005), and plastic snow fencing has been used on the weir panels adjacent to the passage chute to prevent fish from becoming trapped between pickets since 2005. Although the snow fencing was mostly successful in preventing mortalities, fish still became trapped between pickets in 2007. We recommend stretching a double layer of plastic snow fence over the weir panels nearest the passage chute in future years to provide more rigidity between pickets.

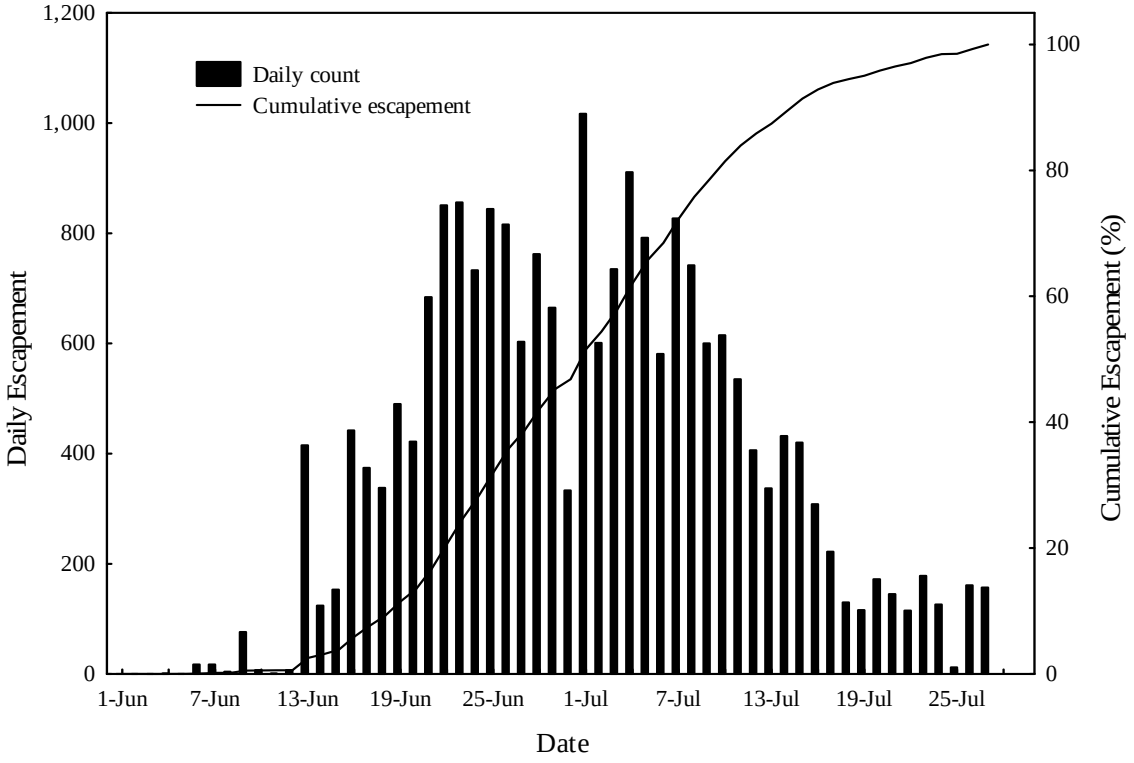

Figure 2. Daily and cumulative escapement of sockeye salmon at the McLees Lake weir, 2007.

Table 2. Estimated age composition (%) of sockeye salmon by stratum at the McLees Lake weir, 2007. Data are only presented for age classes comprising more than 1% of the sample.

	Age			
	1.2	1.3	1.4	2.3
		Stratum 1		
%	0	85	10	5
SE (%)	0.0	7.4	6.3	5.0
n	0	17	2	1
		Stratum 2		
%	3	84	4	8
SE (%)	1.6	3.2	1.8	2.0
n	4	98	5	9
		Stratum 3		
%	0	87	3	10
SE (%)	0.0	3.2	1.6	3.0
n	0	95	3	11
		Stratum 4		
%	2	81	4	13
SE (%)	1.2	3.7	1.9	3.0
n	2	91	5	14
		Stratum 5		
%	0	92	2	6
SE (%)	0.0	2.6	1.3	2.0
n	0	98	2	6
		Stratum 6		
%	3	87	0	11
SE (%)	1.4	3.1	0.0	3.0
n	3	103	0	13
		Stratum 7		
%	3	89	2	7
SE (%)	1.5	2.8	1.1	2.0
n	4	109	2	8
		Stratum 8		
%	1	90	1	7
SE (%)	0.9	2.7	0.9	2.0
n	1	96	1	8
		Total		
%	1	87	2	9
SE (%)	0.4	1.3	0.6	1.0
n	14	707	20	70

Table 3. Estimated sex composition, sample size, and escapement of sockeye salmon by stratum at the McLees Lake weir, 2007.

		Sex			
Stratum	*n*	Female (%)	Male (%)	SE (%)	Escapement
1	23	22	78	7.9	115
2	135	27	73	3.6	1,149
3	135	18	82	3.2	4,015
4	136	41	59	4.2	4,756
5	135	41	59	4.2	5,464
6	135	47	53	4.2	3,667
7	135	50	50	4.1	1,513
8	135	51	49	3.9	749
Total	969	38	62	1.7	21,428

Table 4. Mean length (mm), SE, range, and sample size by sex and age taken from sockeye salmon at the McLees Lake weir, 2007.

	Age				
	1.2	1.3	1.4	2.2	2.3
			Female		
Mean	481	546	534	--	531
SE	3	7	19	--	8
Minimum	449	461	512	--	472
Maximum	540	592	558	551	580
n	7	274	5	1	31
			Male		
Mean	519	573	584	--	568
SE	9	10	7	--	11
Minimum	458	490	525	--	527
Maximum	561	637	624	--	611
n	7	433	15	0	39
			Total		
Mean	494	563	571	--	553
SE	7	11	9	--	14
Minimum	449	461	512	--	472
Maximum	561	637	624	551	611
n	14	707	20	1	70

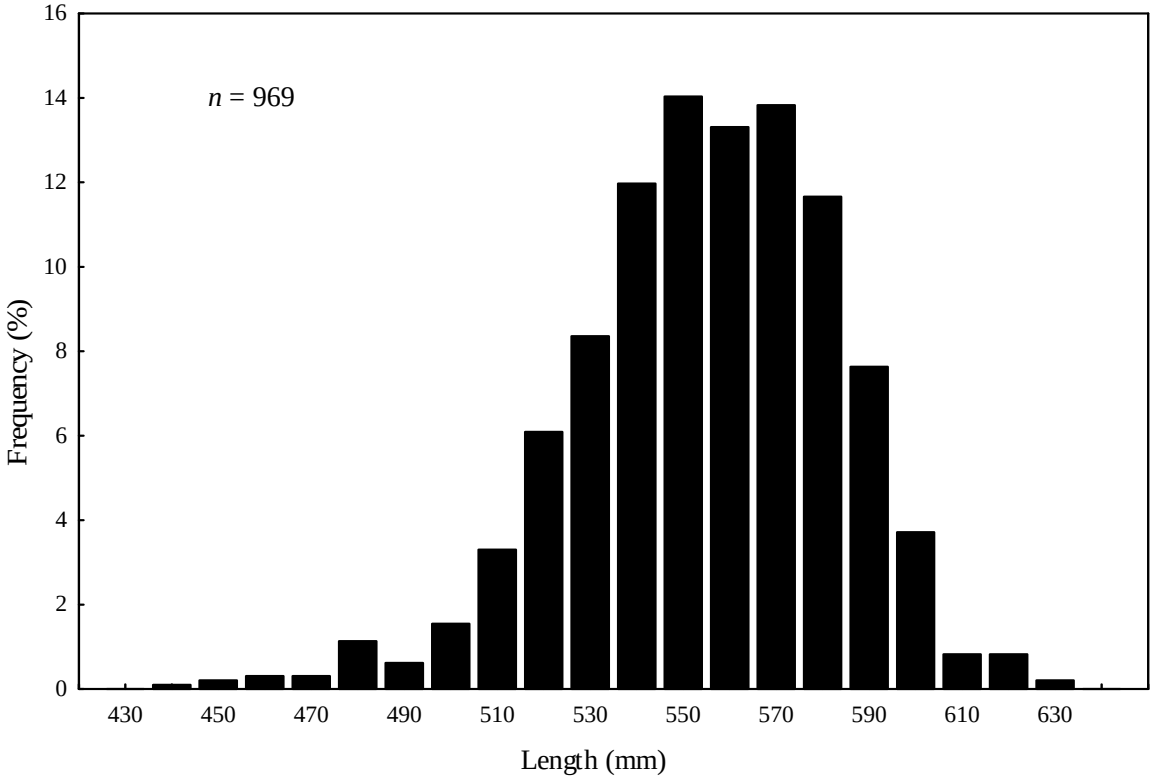

Figure 3. Length-frequency distribution of sockeye salmon sampled at the McLees Lake weir, 2007.

Sockeye salmon escapement in 2007 was greater than the two previous years, but still lower than the first four years of the project (Table 5). We expected a larger return in 2007, mainly because of the age 1.3 component that was produced in brood year (BY) 2002 when escapement was over 97,000 fish (Table 5). We expect a large return again in 2008 because it will include age 1.3 and 2.2 fish from BY 2003 (escapement > 100,000), and age 2.3 fish from BY 2002 (escapement > 97,000). Sockeye salmon run timing in 2007 was later than average and was most similar to the 2002 run (Figure 4). Age composition was similar to previous years in that either age 1.2 or 1.3 fish are dominant, and the lower proportion of females was also similar to past years (Table 6).

Subsistence needs were met at the Reese Bay fishery in 2007. Neither our office nor the local ADF&G manager received any complaints from subsistence fishery participants about their inability to harvest enough fish. However, we do not know what escapement levels are needed to sustain a healthy sockeye population while meeting harvest (primarily subsistence) needs. We need to continue to collect escapement and harvest data so that a time series of production information is available for estimating sustainable harvest levels.

We recommend that USFWS and ADF&G work together to develop specific management objectives to ensure adequate sockeye salmon escapement into McLees Lake and provide for subsistence use. Subsistence harvest of McLees Lake sockeye salmon has averaged 11% of escapement since the weir became operational in 2001, and has only exceeded 20% of escapement during 2005 (Table 7). Although exploitation has been low, development of an escapement goal or other management objectives would help ensure stock sustainability while

Table 5. Annual weir counts of Pacific salmon into McLees Lake, 2001 to 2007.

	Species				
Year	Sockeye	Chinook	Chum	Coho	Pink
2001	45,866	1	--	1	--
2002	97,780	1	--	--	--
2003	101,793	--	--	--	19
2004	40,327	--	3	--	1
2005	12,097	--	1	--	3
2006	12,936	--	--	--	268
2007	21,428	1	--	2	2

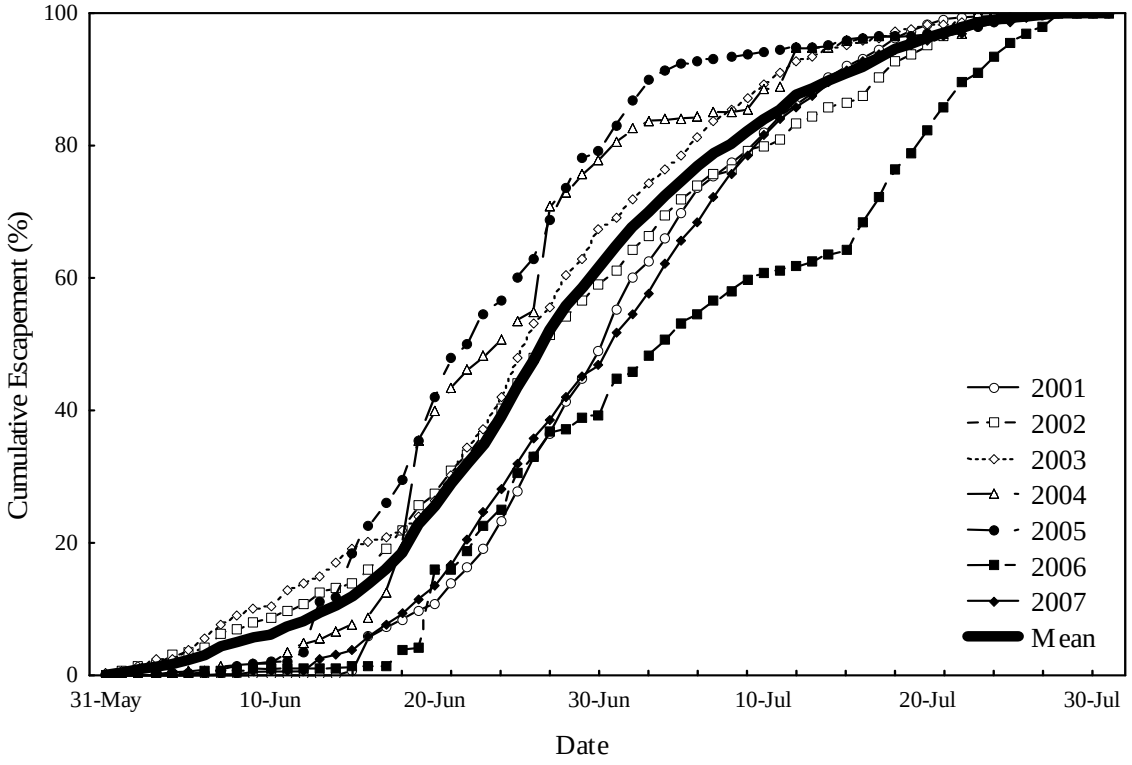

Figure 4. Cumulative escapement of sockeye salmon at the McLees Lake weir, 2001 to 2007.

Table 6. Sockeye salmon sex and age composition (SE in parentheses) at the McLees Lake weir, 2001 to 2007. Data are from previous project reports and are only presented for the three predominant age classes.

		Age (%)		
Year	Female (%)	1.2	1.3	2.3
2001[a]	42	4	94	<1
2002[a]	43	60	32	<1
2003[a]	46	8	78	10
2004	43 (2.2)	54 (2.2)	32 (2.0)	8 (1.2)
2005	38 (2.2)	8 (1.3)	88 (1.5)	2 (0.6)
2006	45 (2.1)	38 (2.0)	58 (2.1)	2 (0.7)
2007	38 (1.7)	1 (0.4)	87 (1.3)	9 (1.0)

[a] Standard errors for estimates not reported.

Table 7. McLees Lake weir escapement, subsistence harvest of sockeye salmon in Reese Bay, Unalaska Island, and subsistence harvest expressed as a percentage of weir escapement, 2001 to 2006. Subsistence harvest data are from Tschersich (2007a).

Year	McLees Lake Escapement	Subsistence Harvest	% of Weir Escapement
2001	45,866	3,389	7
2002	97,780	4,694	5
2003	101,793	4,388	4
2004	40,328	3,771	9
2005	12,088	3,363	28
2006	12,936	1,451	11
Mean		3,286	11

not unduly restricting subsistence opportunities. It would also make management decisions easier to anticipate and could lessen the possibility of future restrictions.

Acknowledgements

We thank Todd Anderson, Lance Sweenhart, and Sean Chamberlain for operating the McLees Lake weir in 2007. We also thank the Qawalangin Tribe for providing fisheries technicians for the project. Finally, we thank Forrest Bowers, ADF&G, and his staff for their assistance in transporting supplies and personnel from Dutch Harbor to the weir site, providing logistical support, and for providing bunkhouse space for the crew while in Dutch Harbor. The U. S. Fish and Wildlife Service Office of Subsistence Management provided funding for this work through Fisheries Resource Monitoring Program as project number FIS 07-405.

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Appendix A. Daily and cumulative escapement of sockeye salmon at the McLees Lake weir, 2007.

Date	Daily Count	Cumulative Escapement
1-Jun	0	0
2-Jun	0	0
3-Jun	0	0
4-Jun	1	1
5-Jun	0	1
6-Jun	17	18
7-Jun	17	35
8-Jun	4	39
9-Jun	76	115
10-Jun	7	122
11-Jun	1	123
12-Jun	7	130
13-Jun	415	545
14-Jun	124	669
15-Jun	153	822
16-Jun	442	1,264
17-Jun	374	1,638
18-Jun	338	1,976
19-Jun	490	2,466
20-Jun	422	2,888
21-Jun	684	3,572
22-Jun	851	4,423
23-Jun	856	5,279
24-Jun	733	6,012
25-Jun	844	6,856
26-Jun	816	7,672
27-Jun	603	8,275
28-Jun	762	9,037
29-Jun	665	9,702
30-Jun	333	10,035
1-Jul	1,017	11,052
2-Jul	601	11,653
3-Jul	735	12,388
4-Jul	911	13,299
5-Jul	792	14,091
6-Jul	581	14,672
7-Jul	827	15,499
8-Jul	742	16,241

Appendix A. continued.

Date	Daily Count	Cumulative Escapement
9-Jul	600	16,841
10-Jul	615	17,456
11-Jul	535	17,991
12-Jul	406	18,397
13-Jul	337	18,734
14-Jul	432	19,166
15-Jul	420	19,586
16-Jul	308	19,894
17-Jul	222	20,116
18-Jul	130	20,246
19-Jul	116	20,362
20-Jul	172	20,534
21-Jul	145	20,679
22-Jul	115	20,794
23-Jul	178	20,972
24-Jul	126	21,098
25-Jul	12	21,110
26-Jul	161	21,271
27-Jul	157	21,428